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L11: Entry 1 of 3 File: USPT Dec 21, 1999

DOCUMENT-IDENTIFIER: US 6003887 A
TITLE: Rotary centering compensator for vehicle steering systems

Brief Summary Text (38):
Use of the differential pressure valve establishes an additional level of resistance to compressive movement of the piston such that turning of the steering wheel requires a steering force sufficient to overcome the total resistance to fluid flow represented by the accumulator pressure and the differential pressure in combination. An orifice may be placed in series with the differential pressure valve to limit the rate of piston movement away from its rest position by further increasing the level of fluid resistance as the rate of flow through the valve increases after breakaway from the rest position.

Brief Summary Text (39):
Free return flow from the accumulator to the pressure chamber upon cessation of a steering force may be provided by a line containing a check valve in parallel with the differential pressure valve and orifice. This parallel line may also contain an orifice for controlling the rate at which the steering system may be returned to its center position.

Brief Summary Text (40):
In a hydraulic embodiment of the invention, the centering cylinder may be pressurized by the power steering system of the vehicle. In a pneumatic embodiment, the centering cylinder may be pressurized by an air brake system of the vehicle. The pressurizing fluid may be provided instead by a hydraulic fluid or air pressurization system separate from other fluid systems of the vehicle. For example, a pressure accumulator system of the type described in the applicant's prior U.S. Pat. No. 4,410,193 may be employed for storing and providing hydraulic fluid under pressure to the centering piston.

Brief Summary Text (47):
However, the invention also contemplates remotely trimmable versions wherein the length of the centering lever to steering system linkage may be changed, or wherein the cam ring is mounted for rotation so that its static position relative to the cam housing may be changed, by a trimming device that is actuated from a remote location, such as the driver's station. One such trimming device for repositioning the cam ring within the housing is a clutch-like mechanism wherein mating conical surfaces on the outer periphery of the cam ring and on the inner periphery of the cylindrical housing wall are disengaged from frictional contact, rotated relative to each other and then reengaged into frictional contact.

Brief Summary Text (48):
Rotation of this cam ring is provided by mounting it on ball bearings that are supported in the circular race of a track plate and are held in spaced apart positions by a bearing spacer plate. To provide the clutch-like mechanism, the track plate rests on and is moveable axially by release bearings driven along bearing ramps in the base member by a release plate that is arranged to be reciprocally rotated in response to an external driving means, such as a release piston contained in a release cylinder. The release piston may be driven to its release position by fluid pressure acting against a return spring. The release

plate also may be reciprocated by an electric solenoid or other driving means connected to the release plate and acting against a return spring.

Brief Summary Text (49):
Rotation of the release plate in one direction drives the release bearings up their ramps causing upward axial movement of the track plate. Such axial movement of the track plate produces upward axial movement of the cam ring and this releases the cam ring from its frictional engagement with the housing wall and permits rotation of the cam ring within the housing. Rotation of the release plate in the other direction drives the release bearings down their ramps causing downward axial movement of the track plate. Such downward movement of the track plate produces downward axial movement of the cam ring and this places the cam ring back into frictional engagement with the housing wall, thereby locking the cam ring in a new static position within the housing.

Brief Summary Text (51):
Other trimming devices provide positive repositioning of the cam ring within the housing. One such device is a gear mechanism driven by a reversible electric motor and connected to the cam ring through a slide plate pivotally mounted on an eccentric (off-center) journal carried by the last driven gear of a gear train. Rotation of this gear by the gear train causes the attached eccentric journal to rotate and this slidingly shifts the slide plate because the journal is fixed eccentrically relative to the rotational axis of the gear. Depending on the direction in which the slide plate is shifted, the cam ring is rotated in either a clockwise or a counterclockwise direction and thereby moved to a new static position in the housing.

Brief Summary Text (53):
As evident from the foregoing, a reversible electric motor is another means for affecting the trimming operation remotely. It is also within the scope of the present invention to employ other types of remotely controllable linear actuators for the trimming means. For example, hydraulic actuators may be used similar to those disclosed in the applicant's prior U.S. Pat. No. 4,410,193. In particular, the cam ring may be connected to a trim piston reciprocally carried within a hydraulic trim cylinder mounted on the vehicle frame and having dual trimming chambers, one on either side of the trim piston. Hydraulic fluid from a fluid system accumulator or other pressurized fluid source may then be used to move the trim piston in either direction and thereby cause corresponding rotation of the cam ring in either direction.

Detailed Description Text (12):
As previously explained, the centering shaft 15 is mounted for both sliding and rotary movements relative to the housing 13. The purpose of these movements is to permit the follower rollers 45, 46 and 47 to travel along their corresponding segments of the cam surface 64, which requires that the cam rollers move in both peripheral directions and in both axial directions in response to rotation and sliding, respectively, of the centering shaft 15. In order to keep the follower rollers in firm engagement at all times with the cam surface 64, centering shaft 15 is biased axially in the direction of arrow B (downward relative to the orientation of FIGS. 3 and 4) by a piston 80 having a piston ring 81 and arranged for reciprocal movement in a cylinder 82. Cylinder 82 has a vent 84 for communicating an ambient air chamber 85 with ambient pressure and an opening 86 for communicating a pressurized fluid with a pressure chamber 88. An extension 90 of the centering shaft 15 serves as a piston rod which carries the piston 80 and is responsive to axial movement of the follower assembly while being biased by fluid pressure in centering chamber 88.

Detailed Description Text (18):
In the embodiment of FIGS. 8-12, the housing base 40' includes a plurality of inclined bearing ramps 94 in which are seated a corresponding number of release

rollers 96. The release rollers 96 ride within corresponding apertures 98 of a release plate 100 that is arranged for rotary reciprocating movement around a central boss 102 when driven by a trimming piston 104 contained in a trimming cylinder 106. A rod 108 of the piston 104 is pivotally connected to an ear 110 projecting radially outward from the release plate 100 as may be seen best in FIGS. 10 and 11.

Detailed Description Text (19):
Resting on top of the release bearings 96 is a track plate 114, which has a lower circular race 116 in which the release bearings 96 ride and an upper circular race 118 in which ride a plurality of ball bearings 120. The ball bearings 120 are held apart at substantially equal spacing by a spacer plate 122, and support the cam ring 52' for rotation relative to the housing wall 56' when the conical outer face 54' is not in frictional engagement with a conical housing surface 112. The ball bearings 120 may rotatably support a cam ring having a flat lower edge, but preferably travel in a circular race 124 on the lower side of the cam ring 52' opposite to race 118 in the track plate 114.

Detailed Description Text (21):
Referring now to FIGS. 12 and 13, the cam ring 52' is shown in its released condition where its outer conical face 54' is no longer in frictional contact with the inner conical surface 112 of housing wall 56'. This released condition is produced by introducing a pressurized fluid into a trim chamber 105 through an opening 107 in an end wall of trim cylinder 106. Such pressurization of the trim chamber 105 causes piston 104 to move from its position shown in FIG. 10 to its position shown in FIG. 11, which in turn causes the release plate 100 to drive release bearings 96 up their corresponding ramps 94, thereby axially moving (raising) track plate 114, ball bearings 120, spacer plate 122 and cam ring 52' relative to the housing wall 56' as shown in FIGS. 12 and 13.

Detailed Description Text (26):
In order to keep the follower rollers in firm engagement at all times with the cam surface 168, centering shaft 154 is biased axially in the direction of arrow B' (downward relatively to the orientation of FIG. 14) by a piston 174 having an outer piston ring at 175 and an inner ring 176 and arranged for reciprocal movement along a central portion of centering shaft 154 so as to be responsive to the biasing force provided by a pressurized fluid supplied to a pressure chamber 178 through an opening 179 in the housing lid 157. The pressure chamber 178 is sealed with respect to ambient pressure by a ring seal 184 between the lid 157 and the housing wall 158, and a ring seal 185 between the housing lid 157 and the centering shaft 154. The piston 174 preferably engages an annular ledge 181 of centering shaft 154 via an annular thrust bearing 182. Such biasing of the centering shaft 154 provides the resistance force opposing movement of the follower rollers out of and away from their respective centering depressions, and also provides the return force which tends to return the follower rollers to their respective centering depressions when the rollers are travelling on the cam surface shoulders on opposite sides of the centering depressions.

Detailed Description Text (27):
In the embodiment of FIGS. 14 and 15, trimming of the selected center position of the steerable wheels is achieved by the interaction of a slide plate 188 with the walls of a slideway 189 located within the cam ring 170 and accessible from the inner edge 171 of the cam ring. The slide plate 188 is moved in response to movement of the eccentric journal 152 as actuated by the reversible electric motor 135 acting through the gear train 130, these components constituting a drive means for reciprocating the cam ring 170 relative to the housing wall 158.

Detailed Description Text (28):
In other words, movement of the eccentric journal 152 in the respective arcuate directions indicated by the arcuate arrows R and L in FIG. 15 causes the engaged

slide plate 188 to rotate the cam ring 170 in clockwise and counter-clockwise directions, respectively, around its rotational axis as viewed from the lever 160. Because the axis of journal 152 is fixed eccentrically to the axis of shaft 150 and driven gear 142, rotation of shaft 150 by the gear train causes a corresponding lateral shift of the axis of the offset journal 152, which in turn moves the cam ring 170 rotationally in corresponding directions, as represented by the double-ended arrow T. Such lateral shifts in the axis of journal 152 also cause radial shifts of the slide plate 188 in slideway 189 as represented by the double-ended arrow M. The structural details of these components are illustrated best in FIG. 16.

Detailed Description Text (36):
While holding the steering wheel to the left in a position giving straight ahead travel, the trim button 230 is pushed momentarily to briefly operate the trim piston and release the cam ring clutch so that the cam ring will rotate into alignment with a new centering position. When the trim button is released, the clutch reengages with the cam followers in their center positions in the cam ring depressions such that the steering wheel will remain in a new "trimmed" position when released by the driver. In other words, the new on-center positions of the cam followers will then maintain the vehicle steering system in a newly centered condition, which provides straight ahead travel of the vehicle that is free from the previously experienced roadway pull to the right and will be maintained even when the steering wheel is released.

Detailed Description Text (39):
Bladder 267 is preferably made of neoprene. Accumulator 250 also includes an upper head 293 and a lower head 294 spaced apart by an outer housing wall 287 and secured together by peripherally spaced bolts 295, only one of which is shown in FIG. 18. Gas chamber 266 is connected to a compressed gas source 278 via a conduit 267, a pressure regulator 281, a conduit 271, a dryer 273, a particle filter 292, a conduit 279, a check valve 283, a solenoid operated cut-off valve 275, and a restrictor orifice 285 for limiting the flow rate to regulator 281.

Detailed Description Text (41):
Gas chamber 266 should be large enough for liquid chamber 304 to receive the entire volume of liquid from chamber 88' without unduly collapsing bladder 267. A bleed passage 286 containing a normally closed vent cock 288 allows liquid chamber 304 to be partially filled with hydraulic fluid up to the level of the top of a filler neck 289.

Detailed Description Text (42):
Gas pressure in chamber 266 acts through bladder 267 to store fluid energy received from the hydraulic side of the system, and to maintain fluid pressure on the liquid side of the piston 80' until such time as the gas pressure is released to ambient atmosphere by actuation of dump valves 270 and/or 282 in response to turning off the system with an on-off switch 290. Switch 290 is connected to an electrical buss 201 by a line 203 containing a circuit breaker 205. The lower dump valve 282 includes a drain line 291 and has the dual purpose of discharging both gas and any liquid (such as condensed water) accumulating in gas chamber 266. A pressure relief valve (not shown) may communicate with the gas chamber side of the accumulator to provide an upper limit to the resistance and return forces that may be generated by piston 80'.

Detailed Description Text (44):
As it is best to deactivate the centering assembly 212 in the event of a failure of the power steering system, a switch 252 for interrupting electrical power to solenoid valves 270, 282 and 275 may be provided for vehicles with power steering systems. Switch 252 is mounted on a pressure sensor 253 located in a hydraulic line 254 in fluid communication with the outlet of the power steering pump (not shown). A loss of pressure at the pump outlet causes switch 252 to open, thereby causing

gas supply valve 275 to close and dump valves 270 and 272 to open for depressurizing gas chamber 266, which in turn depressurizes liquid chamber 304 and centering chamber 88' connected thereto. Vent lines 291 and 297 are each preferably of larger capacity than gas supply conduit 267 to ensure that gas chamber 266 will be depressurized even if gas supply valve 275 fails to close and either dump valve 270 or 282 fails to open with the opening of pressure switch 252.

Detailed Description Text (45):
Accumulator 250 also allows hydraulic pressure in the centering chamber 88' to be precisely varied over a relatively wide range because the gas trapped in gas chamber 266 provides a spring-like return force and this chamber may be sized such that the return force does not vary significantly with compressive piston movement. The gas pressure control may comprise a manual throttle valve (not shown) between conduits 271 and 267, in combination with the pressure gauge 276 to indicate accumulator pressure.

Detailed Description Text (49):
As an alternative to supplying the pressurized liquid directly from the accumulator inlet/outlet fitting 284 to the centering assembly 212 via the direct two-way flow line 220', an alternate centering fluid system 340 may be used to provide additional centering features. Thus, an additional level of resistance to be overcome before turning movement may be initiated is provided by a pressure differential valve 342 in a return conduit 344 also containing an orifice 354.

Detailed Description Text (52):
The orifice 354 may be used to control the rate of fluid flow out of the centering chamber when valve 342 is open. Orifice 354 may be fixed or variable in size and in either case provides a flow resistance that varies in response to the rate of piston movement. If orifice 354 is of variable size, it may be operated by a remotely controlled solenoid 356 to make its flow restriction controllably variable in response to vehicle speed or to a manual selector. Orifice 354 may comprise a solenoid operated throttle valve or a multiported valve with different size outlet orifices. Both the orifice solenoid 356 and the valve solenoid 362 may be controlled automatically by the on-board computer 260 through the use of inputs and outputs similar to those already described for automatically controlling pressure regulator 281.

Detailed Description Text (53):
The pressurized hydraulic fluid available from the accumulator 250 is transmitted to the centering chamber 88' through the inlet/outlet conduit 352 and supply conduits 350 and 353. This accumulator energy provides the return force for reseating the cam followers in the centering depressions upon removal of intentional steering inputs. Should the rate of piston return to its centering position be too rapid and cause the steering system to overshoot its selected center position, an orifice 364 may also be installed in supply conduit 350 to control the rate of fluid flow into the centering chamber. However, such flow restrictions should not prevent a relatively free return of all components to center.

Detailed Description Text (54):
Although alternative fluid system 340 is optional, the differential pressure valve 342 is an important feature because it may provide improved centering stability and steering control. The steering force may vary within the range of resistance represented by valve 342 without generating any steering movement. This valve then opens at its set point and remains open as long as a pressure differential above the set point exists between pilot line 358 and conduit 352. It will therefore remain open while the centering piston is moving and will close when such movement stops because continued flow through orifice 354 will lower the pressure differential below the set point.

Detailed Description Text (55):
Thereafter, when the steering force drops below the opposing return force generated by accumulator pressure through supply conduit 350, the centering piston returns to its rest position as fluid flows from the accumulator through check valve 348. Differential pressure valve 342 in combination with accumulator 250 therefore provides a static resistance force greater than the dynamic resistance force provided by the accumulator alone. The term "static" is used in this specification to distinguish the variable resistance force provided by orifice 354 in response to the rate of fluid flow produced by movement of the centering piston. By comparison, the resistances provided by accumulator 250 and valve 342 are both present without fluid flow.

Detailed Description Text (69):
The follower assembly includes a follower roller 464 for engaging the cam surface 452, and the roller 464 is rotatably mounted on a hollow piston member 466 for biasing the roller against the cam surface in response to a pressurized fluid supplied to a centering chamber 468 through a passage 470 in an elongated cylinder 472. The end of centering chamber 468 opposite to roller 464 is closed by a cylinder cap 474 having an O-ring seal 475 and secured in position by a snap ring retainer 476 (FIG. 30). The cylinder 472 is mounted for rotation in the compartment 460 of the housing 454 by opposing sets of roller bearings 478 and 479. The bearings 479 are protected from dust and other debris by an annular dust seal 480, whereas the bearings 478 are protected from dust and other debris by a cover plate 488 as discussed below.

Detailed Description Text (70):
The cylinder passage 470 is supplied with a pressurized biasing fluid, preferably air, by means of a hollow boss 481 and a port nipple 483 that are sealed to each other for relative movement by an O-ring seal 484. The boss 481 may be formed integrally with the cylinder 472. The respective bottom and top plates 458 and 459 are secured together by four bolts (not shown) that pass through apertures 486 in annular wall 456, and the nipple 483 is welded to the cover plate 488, which in turn is bolted by four bolts 489 (only two of which are shown) threaded into a boss 490 extending upward from top plate 459, as may be seen best in FIG. 30. The centering lever 14 is carried by a centering shaft 492 that may be integrally formed with the cylinder 472 on the bottom side thereof opposite to boss 481.

Detailed Description Text (73):
In the embodiment of FIG. 29, trimming adjustment of the center position of the steering system is accomplished mechanically by rotating the connecting rod 18' with a standard wrench (not shown) in engagement with the usual type of wrench lands 524. Turning the connecting rod 18' while threads 526 at its respective ends are in engagement with corresponding threads within the shank 528 of the two ball joints 21,21 functions as a turnbuckle structure, such that rotation in one direction pushes the ball joints 21,21 further apart, and rotation in the opposite direction pulls the ball joints 21,21 closer together. This changes the center position of the steering system relative to the center position of the follower roller 464.

Detailed Description Text (74):
In lieu of the localized mechanical trimming provided by the connecting rod 18' of FIG. 29, the length of the linkage between the centering compensator 450 and the vehicle steering system may be changed remotely by a hydraulic piston and cylinder assembly, such as the trimming assembly 530 shown in FIGS. 35 and 36. The trimming assembly 530 includes a dual piston assembly comprising a piston 532 that reciprocates in a cylinder 533 and a piston 535 that reciprocates in an axially aligned cylinder 536. A liquid reservoir 538 provides a source of hydraulic fluid (liquid) and is arranged to keep filled the respective centering chambers 540 and 541. The fluid in reservoir 538 is optionally under a slight pressure provided by a spring loaded diaphragm 543 to insure a filling flow.

CLAIMS:

15. An apparatus according to claim 14, wherein a driven gear at a driven end of said gear train is connected to said cam ring through a slide plate engaged by an eccentric journal mounted eccentrically to a rotational axis of said driven gear, said slide plate being slidable in a slideway of said cam ring such that rotation of said driven gear in one direction causes said cam ring to rotate in said clockwise direction and rotation of said driven gear in another direction causes said cam ring to rotate in said counterclockwise direction.

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